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Characterization and Modeling Using Non-Destructive Test (NDT) and Experimental Design Methods of a Self Compacting Concrete (SCC) Based on Mineral Additions

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ABSTRACT

The formulation of an innovative concrete that meets the requirements of a self-compacting concrete (SCC), with acceptable performance in terms of rheology in the fresh state; good fluidity, ease of placing, without segregation as well as good mechanical strength and durability at hardened state has become of great research interest for the last decades. Numerous studies have shown the favorable effects of limestone fillers on the SCC properties. This study aims at investigating the effect of inert mineral addition of limestone fillers with dosages of 10% and 20% grinded to different fine nesses 2000, 3000 and 4000 cm^2/g on the physico-mechanical properties of a fresh self-placing concrete using slump, the L-box and the sieve stability tests. Also, the means of destructive and non-destructive tests (NDT) methods to the assessment of the mechanical performances of SCC at hardened state were used. The use of experiment factorial design method allows us to have behavior laws to predict the mechanical strength response when combined with (NDT) according to a numerical model in such study. Hence, a numerical modeling of mechanical response could be derived by such statistical analysis in regards to the effects of factors and their interaction. The results obtained showed that the incorporation of limestone filler in the composition of the SCC improves the fluidity with limited segregation, as well as the good mechanical performances (resistance to compression and flexion). The numerical modeling of the predicted compressive strength response, in particular at the age of 28 days, is judged to be with an acceptable determined coefficient R^2 equal to 0.994.

1. INTRODUCTION

The fillers are essential components in the formulation of Self Compacting Concrete (SCC); in the beginning, their main purpose was the reduction of the cost of concrete product. This aims to respect the environment protection by both the reduction of CO_2 emissions from the cement manufacturing industry and the to avoid the depletion of natural resources later [1, 2].

Limestone as a by product fines are the mostly used as an addition or substitution to cement or even as a partial replacement to sand in the formulation of SCC [3, 4].

Despite the recent use of other types of fillers such as natural stone waste (carbonaceous or siliceous rock wastes), volcanic type powders (Basalt powder) and pozzolan [5-7]. Industrial wastes such as fly ash, silica fume, glass powder, cement kiln dust, and copper waste has become of interesting utility in concrete construction industry [8-10]. Further, the by-products of iron manufacturing; granulated slag from blast furnace and steel slag aggregates or cupola slag powder could contribute efficiently as a replacement for cement to fulfill technical, economical and environmental roles for a sustainable development aims in a much more climate change requirements era [11, 12] In addition, the waste valuation of other sectors alike manufacturing and agriculture has known its continuous development for SCC formulations [13-15].

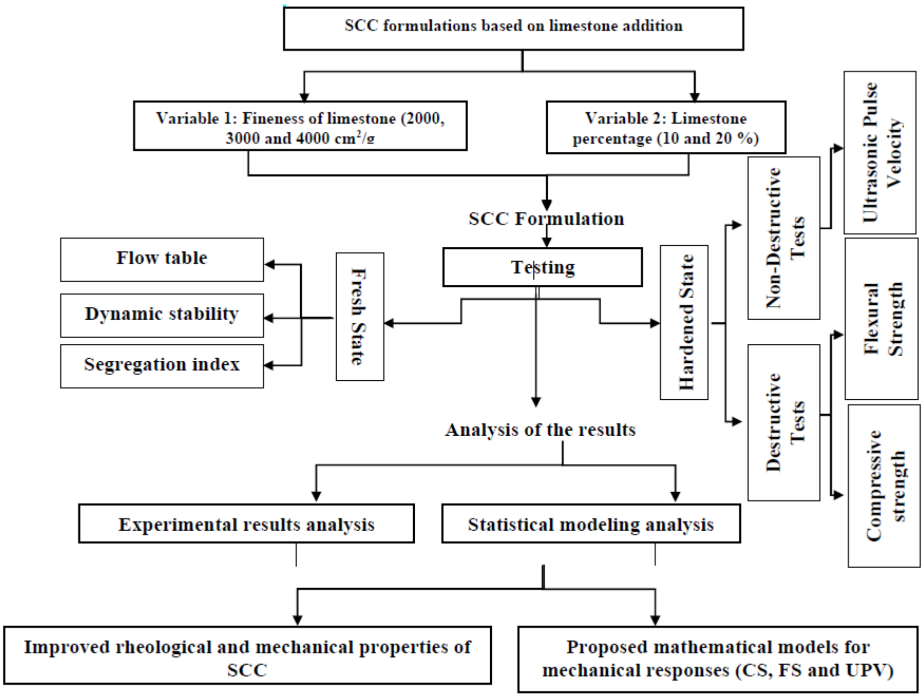
Many studies have shown the effectiveness of the use of limestone filler in the formulation of SCC; it improves rheological properties as well as the mechanical strength [16-20]. Other studies show even the effectiveness of the limestone filler in the fibrous concretes whether it is metallic [21], plastic [22] or bamboo fibers types [23].

In order to ensure that the formulated SCC has good properties in the fresh and hardened state it is preferable to predict them upstream; some studies have used computational fluid dynamics to predict the fluidity and flow behavior [24-26]. Others have used the extreme learning machine and deep learning model [27] to predict the fresh properties. There are also those who have used the response surface methodology or artificial neural networks to predict rheological and mechanical properties.

This research aims to study the effect of the addition of inert minerals of limestone fillers at two dosages (10% and 20%) and different fineness grading 2000, 3000 and 4000 cm^2/g. The action of the volume of equivalent mortars constituted of fillers, fine sand fraction and cement subjected to the super plasticizer (SP) effect on the due paste could be appreciated for higher dosages of used limestone fillers up to 20%.

As such combined influence with greater limestone fineness on the rheological as well as physico-mechanical properties of a self-compacting concrete could be investigated. In the fresh state by the evaluation of the fluidity (spread Slump test), the ease of casting in confined area (L-box test), the stability (segregation index test) has been assessed. The destructive and non-destructive tests (NDT) as means of evaluating the mechanical performance of self-placing concrete have been performed. Further, In the present study we will develop a numerical model by the design experiment method JMP to predict the mechanical strength response when combined with Non Destructive Tests (NDT) to asses a sustainable Self compacted concrete within acceptable quality for construction use.

The issue of such experimental testing program results let us to see the benefic role of limestone dosage up to 20% coupled with greater fineness around 4000 cm^2/g on the behavior of SCC formulated mixtures at the fresh and hardened state. In addition; the statistical analysis permitted numerical mathematical equation models to predict the mechanical response for compressive, flexural and ultrasonic velocity strengths values at a good satisfying correlation coefficient above 0.99.



2. MATERIALS

The cement used is CEMII A 42.5. Its chemical composition is summarized in Table 1. Physical characteristics are shown in Table 2.

Table 1. Chemical composition of the used cement

Elements	Content [%]
SiO_2	17.7
Al_2O_3	4.6
Fe_2O_3	2.99
CaO	62.7
MgO	1.90
K_2O	0.67
Na_2O	0.05

Table 2. Physical and mechanical properties of the used cement

Property	Value	Unit
Specific density	3.1	(g/cm^3)
Fineness	3950	(cm^2/g)
Initial setting time	2:40	H:mn
Final setting time	4:20	H:mn
Compressive strength (7 days)	22.3	(Mpa)
Compressive strength (28 days)	48.8	(Mpa)

Local crushed gravels from the region at two fractions (3/8) and (8/15) for the composition of SCC were used. The Local crushed gravels from the region at two fractions (3/8) and (8/15) for the composition of SCC were used.

The silicious used fraction of sand comes from the Oued Souf region (South-east of Algeria). All physical characteristics of aggregates are summarized in Table 3.

Table 3. Characteristics of aggregates

Characteristics	Dune sand	Gravel 3/8	Gravel 8/15
Absolute density	2.7	2.56	2.57
Bulk density	1.7	1.36	1.35
Porosity	//	45.4	47.64
Compactness	//	54.6	52.35
Sand modulus	0.80	////	

The mineral additions as Limestone fillers (L) from the nearby national company of aggregates ENG El khroub – Constantine was employed. Its absolute density is of a value 2.7 g/cm^3.Two dosages of 10% and 20% associated to the three fineness F2, F3 and F4 (2000, 3000 and 4000 cm^2/g) were kept for the formulation of SCC mixtures used in the present experimental program. The chemical compositions of this Limestone fillers are summarized in Table 4.

Table 4. Chemical composition of limestone fillers

Chemical Element	Composition F2	of Limestone fillers (%) F3	F4
SiO_2	0.10	0.18	0.15
Al_2O_3	0.00	0.00	0.01
Fe_2O_3	0.01	0.01	0.00
CaO	58.21	58.29	58.22
MgO	0.013	0.11	0.13
SO_3	0.04	0.03	0.08
K_2O	0.01	0.01	0.00
Na_2O	0.06	0.05	0.06
Cl	0.00	0.002	0.003

The admixture used in our study is a super plasticizer (SP), a high water reducer (MEDAFLOW 30). It is designed based on polyether carboxylates which considerably improve the properties of concretes. It allows to obtain concretes of very high quality.

3. PREPARATION OF SCC MIXTURES

For the formulation of the self-compacting concrete we have respected the necessary conditions based on the compositions proposed by AFGC (French Association of Civil Engineering). A set of three specimens is hold all along the program required tests to assess the different properties of SCC mixtures Table 5. The SCC_{10F2}, SCC_{10F3} and SCC_{10F4} SCC refers to the SCC with Limestone dosage of 10% and a fineness of F2=2000 (cm^2/g), F3=3000 (cm^2/g), and F4=4000 (cm^2/g) respectively. The SCC_{20F2}, SCC_{20F3} and SCC_{20F4} SCC refers to the SCC with Limestone dosage of 20% and a fineness of F2=2000 (cm^2/g), F3=3000 (cm^2/g), and F4=4000 (cm^2/g), respectively.

Table 5. Composition of one cubic meter of SCC concrete formulated by the AFGC method

Mixes	S Kg/m^3	Gr (3/8) kg/m^3	Gr (8/15) kg/m^3	C kg/m^3	W kg /m^3	SP Kg/m^3	L Kg/m^3
	G/S=0.9			E/(C+F)=0.4		1.2 (%)C	10 & 20(%) of C
SCC_{10F2*}	766	423	423	400	176	5.280	40
SCC_{10F3}	766	423	423	400	176	5.280	40
SCC_{10F4}	766	423	423	400	176	5.280	40
SCC_{20F2**}	766	423	423	400	176	5.280	80
SCC_{20F3}	766	423	423	400	176	5.280	80
SCC_{20F4}	766	423	423	400	176	5.280	80

*SCC_{10F2}:10% Limestone fillers (L) with fineness of 2000 cm^2/g **SCC_{20F2}:20% Limestone fillers (L) with fineness of 2000 cm^2/g

4. RESULTS AND DISCUSSION

4.1 The fresh state

4.1.1 Flow table test

In regards to standard value of the flow diameter are usually in the range between 60 and 75 cm for SCC mixtures. It could be observed from Figure 1 that the higher percentage of the fineness of the limestone filler increases the water demand, which causes a decrease of workability expressed in the slow spread of the SCCs [3, 27, 28]. It is observed that the fluidity is slightly greater by increasing the SSB of limestone for all most the mixes.

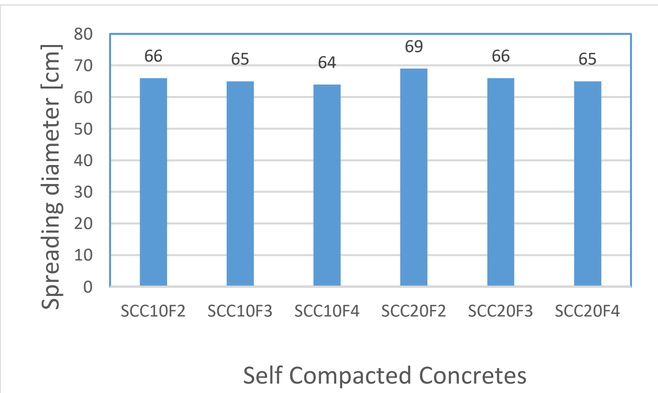


Figure 1. Flow table test results for SCC mixtures

Nevertheless, the higher dosages of limestone filler increase the fluidity; this can be explained by the inert effect of the limestone filler its grain nature and shape [20]. So, the increase in the volume of paste by the addition of limestone filler reduces the intergranular friction by improving the flow of the SCC. The fine particles integrate in the voids and release the trapped water which improves the fluidity [9].

Thus, the SCC with incorporation of limestone fillers are with higher workability that is related to fillers dosage of such mixtures which are much more fluid with a good mobility. One could conclude that the introduction of the limestone fillers at the percentages of 10 and 20% has a meaningful effect on the workability of the tested SCC's types.

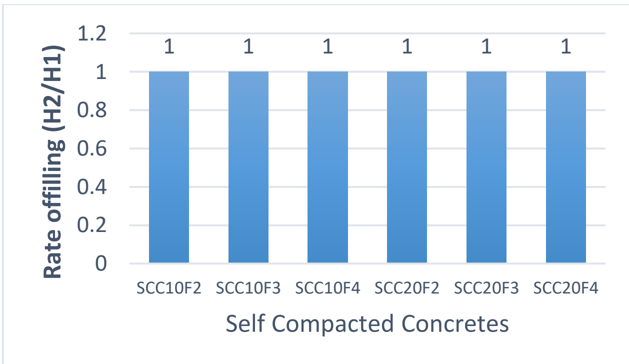


Figure 2. L-box test results for SCC mixtures

4.1.2 Dynamic stability (L-box test)

It is noticed in Figure 2 that all the prepared SCCs have H2/H1 = 100% and the incorporation of limestone filler in mixtures up to 20% ensures an ease of casting for such mixtures. Furthermore, the variation of the fineness of limestone fillers with BSS that ranges from 2000 to the maximum value 4000 cm^2/g and the dosage of filler 20% does not negatively affect the passage and filling capacity of SCC and consequently permit the ease of casting in confined zones that contribute to the dynamic stability [19].

4.1.3 Static stability (Segregation index)

It is noticed in Figure 3 that all the SCCs with 10% of calcareous filler have a segregation rate lower than 15%, synonymous of a correct stability; thanks to the good compactness and the granular distribution that gives these fillers to the cement matrix of the mixtures. On the other hand, at greater percentage with 20% these show a critical segregation rate ranging from around 14 to 18%, which is explained by a bad cohesion between the cement particles and the filler once the dosage of the calcareous filler exceeds 10%. Above 15% fines, the water demand decreases and the fillers begin to behave as a water-reducing admixture and the interaction of cement-fines-aggregates causes a recovery of the occluded air [27, 28].

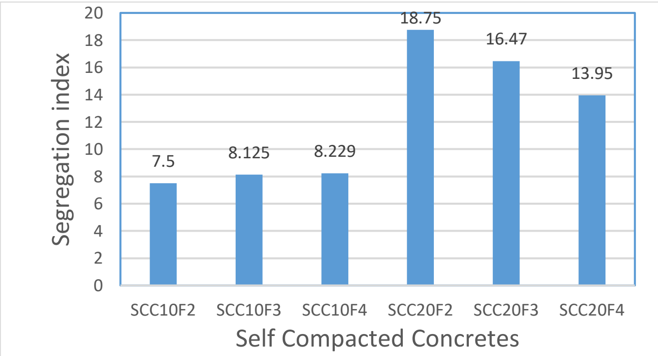


Figure 3. Segregation index test results for SCC mixture

4.2 The hardened state

4.2.1 Compressive strength (CS)

The compressive strength (CS) is estimated at 28 days of hardening and presented in the Figure 4. The minimum value of the mechanical strength is 66.26 MPa (SCC_{10F2}); it refers to the SCC which presents the minimum value of SSB 2000 cm^2/g and dosage of filler 10%. Mechanical resistance increases with increasing BSS and dosage of filler up to a value equal to 85.6 MPa (SCC_{20F4}); the SSB that presents the maximum value of the BSS 4000 cm^2/g and the dosage of filler 20%. It is noted that the increase in the SSB of the limestone filler; increases the compressive strength thus the increase greater dosage of limestone filler increases the compressive strength. Indeed, the obtained values for CS at a dosage of 10% for limestone show a percentage of improvement up to around 20% for SCC_{10F2} (BSS= 2000 cm^2/g) compared to SCC_{10F4} (BSS= 4000 cm^2/g). Furthermore, the percentage of 20% limestone fillers incorporation register an increase of up to 25% for SCC_{20F2} and SCC_{20F4}, respectively.

This, could be explained by the filling effect of the limestone powder which enhances the mechanical resistance The increases in strength are related to the improvement of the compactness obtained by the addition of fines, on the other hand the decreases are mainly due to the increase of the W/C. The optimum content of limestone fines which allows the highest strength to be obtained is around 15% [28, 29].

4.2.2 Flexural Strength (FS)

Figure 5 presents the flexural strength (FS) at 28 days age of hardening for the different SCC studied mixtures. The minimum value of the flexural strength is 6.88 MPa for SCC10F2 and increases up to 9.16 MPa for SCC20F4, respectively. It is mainly depending on the degree of fineness and dosage of limestone filler. Again, it is noted that important fineness (BSS) of the limestone filler increases the flexural strength, thus the higher is the dosage of limestone filler up the greater is the flexural strength recorded overall the studied SCCs. This percentage reaches 20% once comparing SCC10F2 with SCC20F4 mixes; this is in accordance with other research study [30].

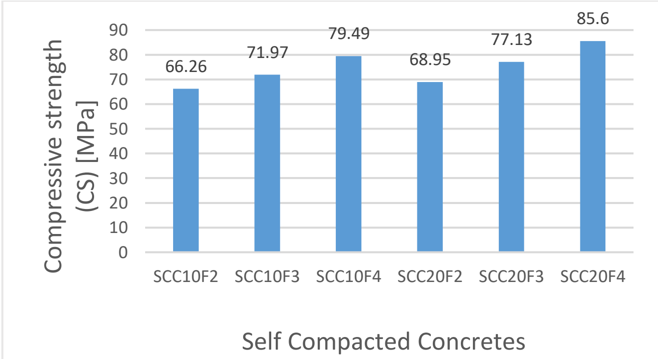


Figure 4. Evolution of the compressive strength of SCC mixtures

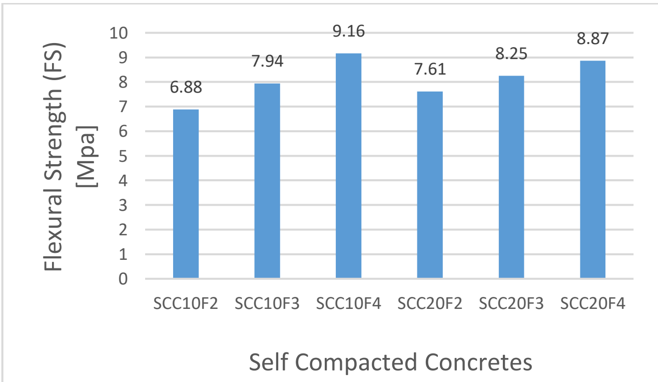


Figure 5. Evolution of flexural strength of SCC mixtures

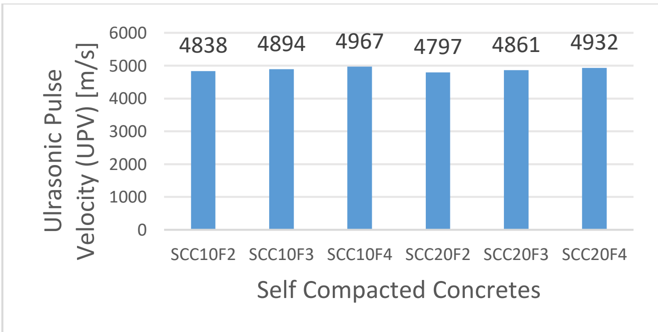


Figure 6. Evolution of ultrasonic pulse velocity of SCC mixtures

4.2.3 Ultrasonic Pulse Velocity (UPV) - NDT test

The Ultrasonic Pulse Velocity is determined at 28 days age of hardening and presented in the Figure 6. The Ultrasonic Pulse Velocity values of all the SCC are greater than 4000 m/s which means excellent resistance and proves the good quality of the confected SCC concrete based on limestone addition. It can be seen that combined higher SSB of the limestone filler or the dosage increases the ultra-sonic speed. Which reflected the increase in the mechanical resistance of almost SCC mixtures. One can conclude that these results of NDT test correlated well with compression test previously discussed and judged to be more reliable in assessing the concrete of the SCC with limestone incorporation filler in the present study as reported by other research work [31].

5. MODELING OF THE MECHANICAL RESPONSE (CS-FS-UPV)

5.1 Correlation of (CS, FS – UPV)

The results of the experimental tests characterize the mechanical behavior of self-compacting concrete with different Specific Surface of Blaine (BSS) and content of limestone powder (D%) Table 6. The six (3*2) experiments proposed by full factorial design were performed; Table 7 summarizes the values of each factor and their respective levels.

The correlations between the observed and the predicted values of compressive strength, flexural strength, and Ultrasonic Pulse Velocity (UPV) (m/s) are given in Figure 7. it can be observed that the generated points dissipated along the trend line, in this way, the models yielded a good expectation power.

Table 8 collects the Summary of Fit results which shows a high correlation coefficients value. The R square for CS, FS, and UPV is 0.997,0.998, and 0.997, respectively.

Table 6. Observed results of mechanical response for statistical modeling of studied SCC mixtures

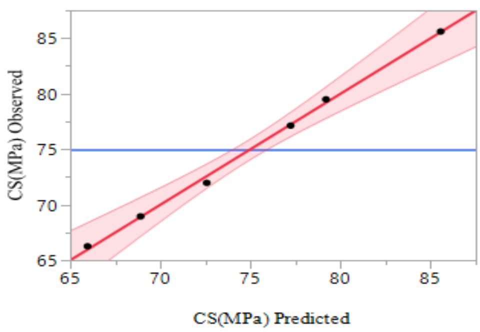
Mixes	SSB (cm²/g)	(L) (%)	Comp- Strength CS(MPa)	Flex- strength FS(MPa)	Ultrasonic Velocity UPV(m/s)
SCC_{10F2}	F2=2000 F3=3000	10	66.26	6.88	4838
SCC_{10F3}	F4=4000 F2=2000	10	71.97	7.94675	4894
SCC_{10F4}	F3=3000 F4=4000	10	79.49	9.167	4967
SCC_{20F2}		20	68.95	7.618	4797
SCC_{20F3}		20	77.13	8.253	4861
SCC_{20F4}		20	85.6	8.873	4932

Table 7. The experimental ranges and factors level

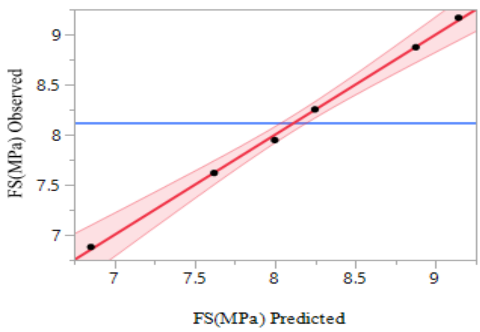
Levels	D (%).	BSS (cm²/g)
-1	10	2000
0	-	3000
+1	20	4000

Table 8. Summary of fit

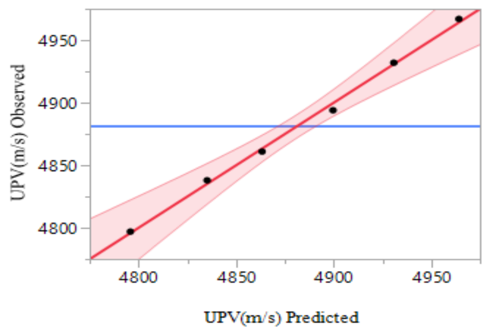
	CS(MPa)	FS(MPa)	UPV(Km/s)
R^2	0.997	0.998	0.997
Adjusted R^2	0.994	0.997	0.992
RMSE	0.529	0.044	5.307
Mean of response	74.9	8.122	4881.5



(a) Compressive strength



(b) Flexural strength



(c) Ultrasonic pulse velocity

Figure 7. Evolution of correlation between actual and predicted values

5.2 Analysis of variance

Table 9 shows the results of ANOVA (Analysis of Variance) in which we present the degrees of freedom, the Sum of Squares, mean square, F-ratio, and the probability.

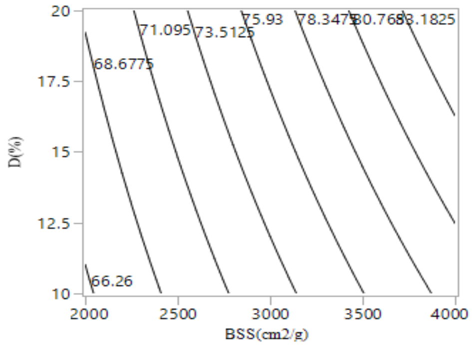
The probability (Prob.> F) values for CS, FS, and UPV is 0.0032, 0.0017, and 0.0043, respectively (Prob. > F) are lower than 5% that allowed and considered evidence that there is at least one significant effect in the model.

5.2.1 Compressive strength (CS)

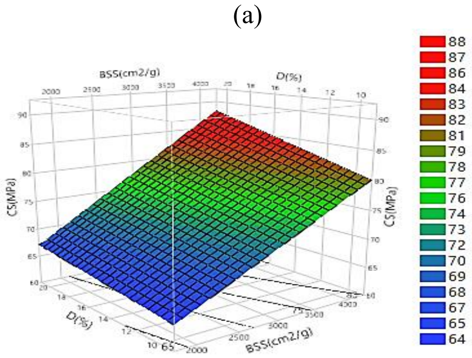
Figures 8 and 9, illustrated the graphical results of compressive strength of self-compacting concrete with different content and finesse of limestone powder. According to the effect test, Table 10, p-values are lower than 0.05 thus, revealing that all of the independent variables considered contrariwise the interaction is not statistically significant. (p-values bigger than 0.05).

From Figures 8-a, 8-b, it can be noted that an increase in the Blaine Specific Surface (BSS), led to increasing the compressive strength, While, the increase in the content of limestone powder has a slight influence on the compressive strength. The interaction plots of compressive strength are presented in Figure 9b. the intersection of the two lines Indicates that interaction of factors has no considerable effect on this response. The empirical equation for the compressive strength this given in Eq. (1).

$$CS(MPa) = 74.9 + 7.47\frac{BSS - 3000}{1000} + 2.32\frac{D - 15}{5} + 0.855\frac{BSS - 3000}{1000}.\frac{D - 15}{5} \quad (1)$$

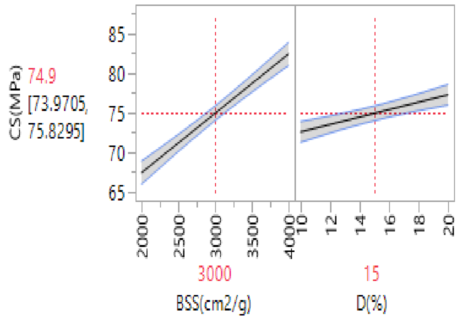


(a)



(b)

Figure 8. (a) Isoresponse curves and (b) response surfaces of compressive strength



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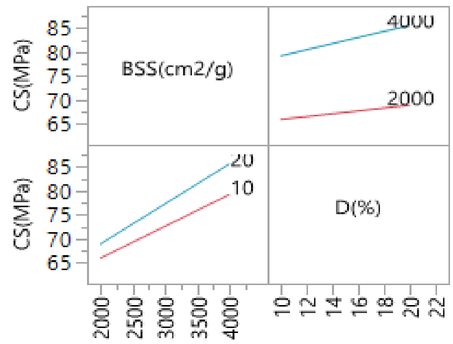


(b)

Figure 9. (a) Main effect plots and (b) interaction plots of compressive strength

5.2.2 Flexural strength (CS)

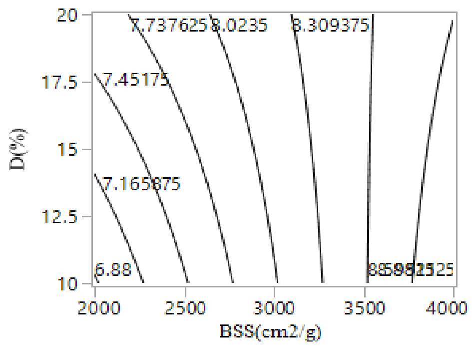
Figure 10 (a) and (b) show the iso-response and surface response for flexural strength SCC specimens. The Iso-response figure shows that the flexural strength increases from 6.88to 8.90 with increasing limestone powder BSS. It can be also noted from the surface response that the increase in the (BSS), led to increasing the flexural strength. While, the increase in the content of limestone powder has a small influence.

Table 9. Analysis of variance (ANOVA) for derived models

	Source	degree of freedom	Sum of squares	Mean square	F -ratio
CS (MPa)	Model Error Total	3	258.60797	86.2027	307.8483
		2	0.56003	0.2800	Prob. > F
		5	259.16800		0.0032*
FS (MPa)	Model Error Total	3	3.4965095	1.16550	587.9636
		2	0.0039645	0.00198	Prob. > F
		5	3.5004741		0.0017*
UPV (m/s)	Model Error Total	3	19413.167	6471.06	229.7416
		2	56.333	28.17	Prob. > F
		5	19469.500		0.0043*

Table 10. Effect test

	Model term	Estimation	standard Error	t ratio	Prob. > |t|
CS (MPa)	Constante BSS(cm^2/g)	74.9	0.216031	346.71	<.0001*
	D (%)	7.47	0.264583	28.23	0.0013*
	BSS (cm^2/g)*D(%)	2.3266667	0.216031	10.77	0.0085*
		0.855	0.264583	3.23	0.0839
FS (MPa)	Constante BSS(cm^2/g)	8.1229583	0.018176	446.90	<.0001*
	D (%)	0.8855	0.022261	39.78	0.0006*
	BSS (cm^2/g)*D(%)	0.1250417	0.018176	6.88	0.0205*
		-0.258	0.022261	-11.59	0.0074*
UPV (m/s)	Constante BSS(cm^2/g)	4881.5	2.166667	2253.0	<.0001*
	D (%)	66	2.653614	24.87	0.0016*
	BSS (cm^2/g)*D(%)	-18.16667	2.166667	-8.38	0.0139*
		1.5	2.653614	0.57	0.6288



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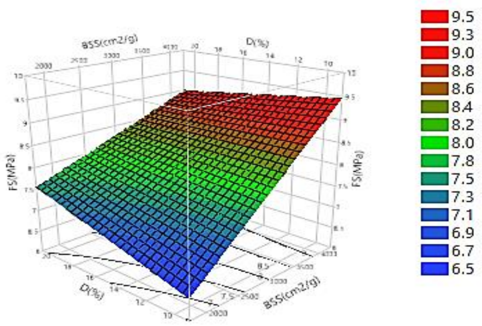

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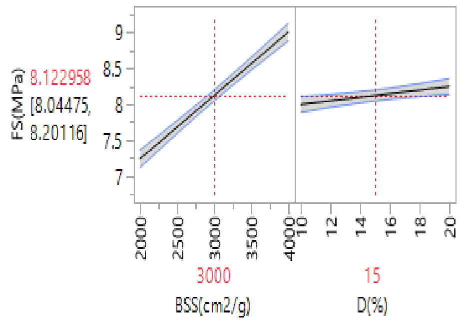
Figure 10. (a) Isoresponse curves and (b) response surfaces of flexural strength



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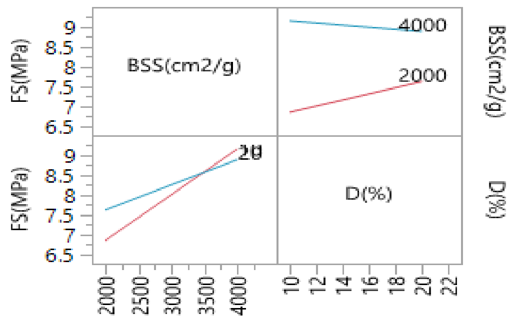


(b)

Figure 11. (a) Main effect plots and (b) interaction plots of flexural strength

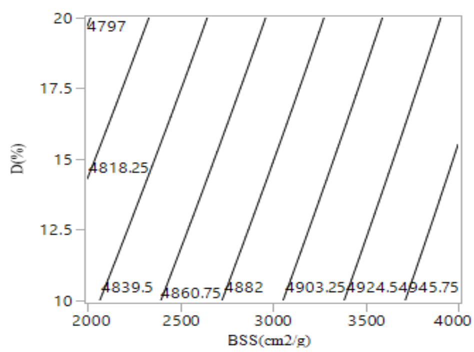
Figure 11.a (Main effect) describe the effect of the two factors on the flexural strength it may be noted that the BSS of limestone powder reproduces a stronger positive effect on the flexural strength, in the same context, the limestone powder content has a small positive effect on this response. These results are dependable with the estimated coefficients (Table 10) and Eq. (2);

Figure 11.b shows interaction plots of flexural strength, it can be observed that the two lines intersect with each other, which indicates that interaction effects of factors have a considerable effect on response.

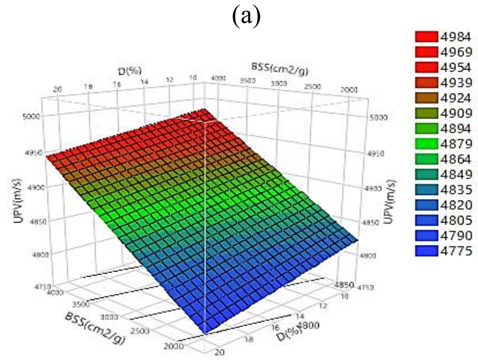
$$FS(MPa) = 8.12 + 0.885\frac{BSS - 3000}{1000} + 0.125\frac{D - 15}{5} - 0.258\frac{BSS - 3000}{1000}.\frac{D - 15}{5} \quad (2)$$

5.2.3 Ultrasonic Pulse Velocity (UPV) - NDT test

Figure 12 (a) and (b) show the iso-response and surface response show clearly that the increase of BSS of limestone powder increases the Ultrasonic Pulse Velocity, remarkably. Indeed, the content of powder presents a little negative effect on the response.



(a)



(b)

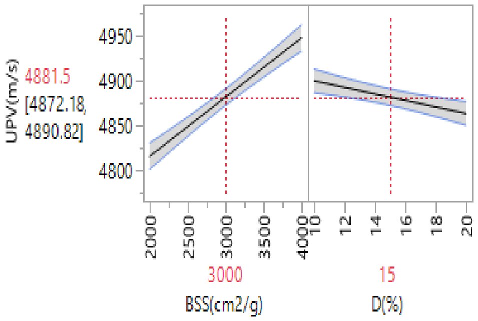
Figure 12. (a) Isoresponse curves and (b) response surfaces of UPV (m /s)

The optimum conditions of UPV were 10% limestone powder and the fineness 4000 g/cm^2.

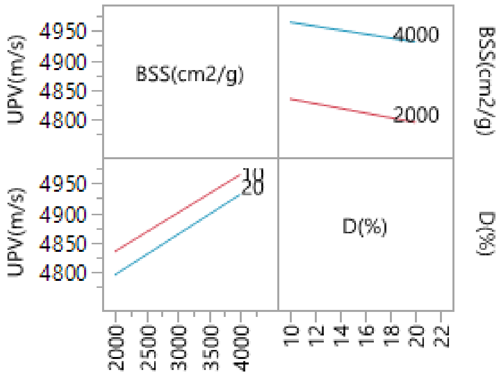
In the same context, and according to the test effect Table 7 above, it has been observed that the BSS of limestone powder is the most influencing factor in the Ultrasonic Pulse Velocity, while the content shows a second-order effect; contrariwise the interaction does not affect the response. these results were confirmed by the main effect and interaction plots Figure 13.

The mathematical model of Ultrasonique Pulse Velocity is written in Eq. (3).

$$UPV\left(\frac{cm2}{g}\right) = 4881.5 + 66\frac{BSS - 3000}{1000} - 18.16\frac{D - 15}{5} + 1.5\frac{BSS - 3000}{1000}.\frac{D - 15}{5} \quad (3)$$



(a)



(b)

Figure 13. (a) Main effect plots and (b) interaction plots of UPV (m /s)

6. CONCLUSIONS

Based on experimental obtained results, and numerical modeling in the present study to characterize SCC compositions based on limestone mineral additions the following conclusions could be drawn:

- The limestone filler incorporation improves the rheological properties mainly, fluidity, the dynamic stability and the static stability (limited segregation) of the SCC.
- Contents up to 20% of limestone addition in the formulation of SCC enhance the mechanical performances (compressive and flexural strengths).
- Higher Blaine Specific Surface (BSS) of limestone addition in the formulation of SCC has a benefic effect on the compressive strength, flexural strength and Ultrasonic Pulse Velocity. The increase reached a maximal percentage of 25% for SCC20F4 (20% L) and F4=4000 cm^2/g).
- The non-destructive method of UPV could be a reliable mean to determine the mechanical performances for a better SCC quality assessment.
- Based on the statistical analysis it could be concluded that both the Blaine Specific Surface (BSS) and the content of limestone have their effect on the mechanical resistance but the SSB is the most influent.
- The numerical modeling by the JMP method gives a good correlation of predicted mechanical surface responses and the observed experimental test results at a determined coefficient superior to 0.99. The outcome of the present statistical analysis, let us to suggest a numerical models to predict the compressive strength (CS), the flexural strength (FS) as well as the Ultra Pulse Velocity (UPV) at the age of 28 days, taking into account the interaction of two parameters (dosages (%) and fineness grade BSS) of limestone addition based formulated Self Compacting Concrete. The mathematical equation models are reported above (1), (2) and (3), consecutively cited in section 5.

Finally, the present research study on the use of limestone additions emphasizes the valuation of such recovery of mineral waste in its technical, economic and ecological side advantages. Also, our contribution proposed new mathematical numerical equation models for mechanical response assessment of SCC formulation based on limestone additives.

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NOMENCLATURE

SCC	Self Compacting Concrte Mixture

L	Limestone addition
SCC_{10F2}	SCC with Limestone dosage of 10% and a fineness of F2=2000 (cm^2/g)
SCC_{10F3}	SCC with Limestone dosage of 10% and a fineness of F3=3000 (cm^2/g)
SCC_{10F4}	SCC with Limestone dosage of 10% and a fineness of F4=4000 (cm^2/g)
SCC_{20F2}	SCC with Limestone dosage of 20% and a fineness of F2=2000 (cm^2/g)
SCC_{20F3}	SCC with Limestone dosage of 20% and a fineness of F3=3000 (cm^2/g)
SCC_{20F4}	SCC with Limestone dosage of 20% and a fineness of F4=4000 (cm^2/g)
CS	Compressive strength using compression tests (MPa)
CF	Flexural strength using destructive flexural tests (MPa)
UPV	Ultra Sonic Pulse Velocity Using NDT methods (m/s)
BSS	Blaine Specific Surface(cm^2/g)